Next Generation FANS over Inmarsat BGAN

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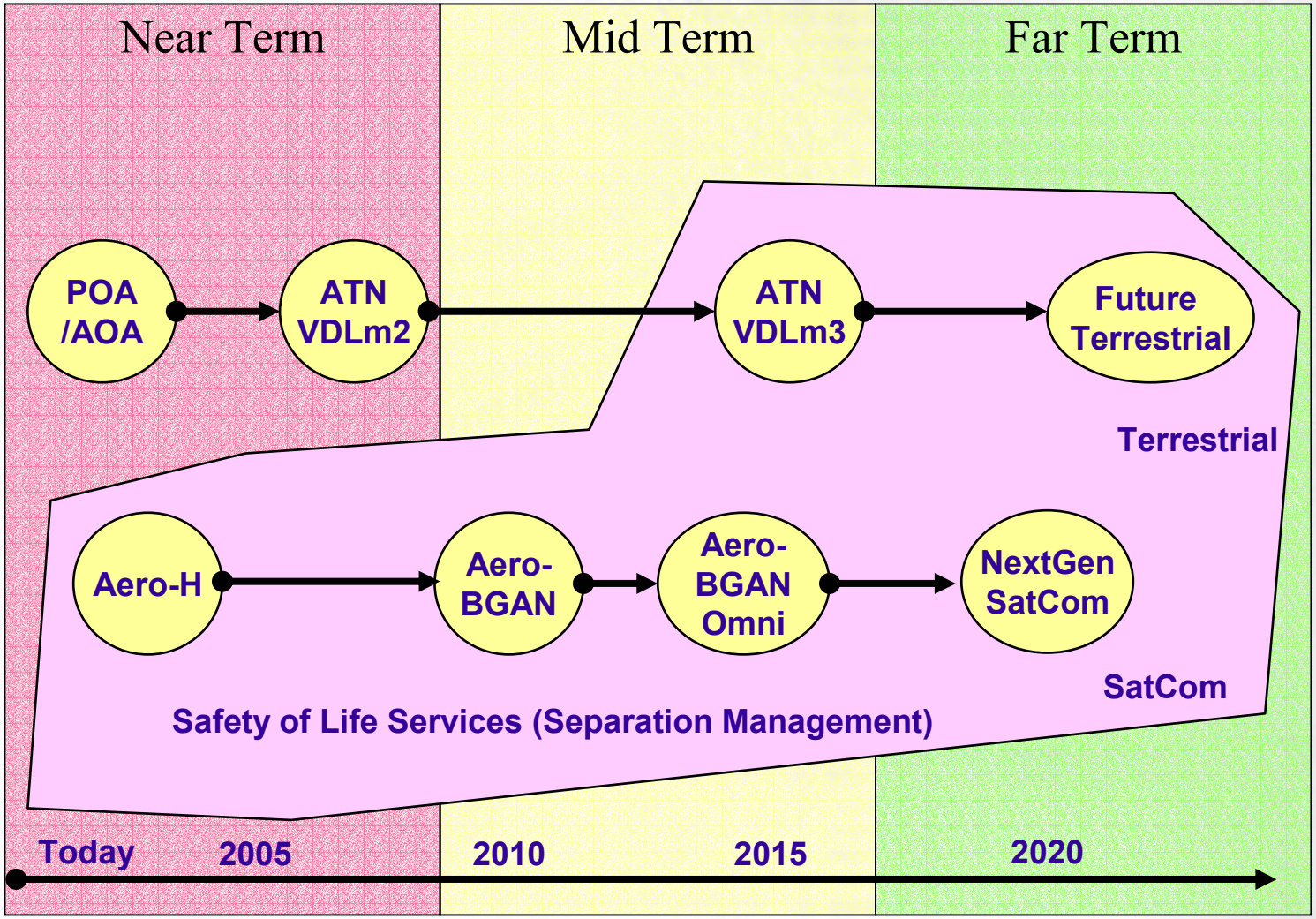
Motivation

- The majority of credible future ATM operational concepts are based, in part, on the negotiation and clearance of conflict free 4-D trajectories
  - Requires a pervasive air-ground datalink enabling direct communication between ground automation systems and the FMC (Flight Management Computer)
- Numerous datalink technologies, supported by the standards bodies, are competing to become the standard
  - e.g. CPDLC ATN message set over VDLm2 or VDLm3
  - But only one, FANS over SatCom, is currently used operationally with functionality similar to the intended end goal
- FANS exhibits certain limitations (latency, service cost, avionics cost, voice service) that can be overcome via the next generation Inmarsat system*

*Inmarsat announced planning timeline pre-operational trials of Aero-BGAN Safety services circa. 2010 during Datalink Users Forum Meeting Feb. 3-5, 2004 San Francisco, CA

Transition Opportunities for Aero-BGAN



Terrestrial Datalink Deficiencies

	Channel Throughput	Media Access	Latency	Capacity	Priority / Pre-emption
Plain Old ACARS	2400 bps peak, 300-600 bps average	CSMA	~30 sec, tied to channel throughput	11 Channels (reused ~39 times in NAS)	No
VDLm2	31.5 kbps peak, 3-6 kbps average	CSMA	~5-20 sec, tied to channel throughput	1 currently, 3 more planned	No
VDLm3	~6 kbps peak, ~2.4 kbps average	DAMA / TDMA	~2 sec, depending upon QoS	Potential for many channels	Yes
BGAN	432 kbps peak, ~160 kbps average	DAMA / TDMA	2-5 sec, depending upon QoS	640 / satellite, 2 satellites	Yes

Operational Benefits & Services

Operational Benefits	C&S Services

• Reduced separation
  • From: 30nmi lat. x 30nmi lon.
  • To: 10nmi lat. x 10nmi lon.
Focus of GCNSS Operation Analysis
	• ATC party-line voice
	• Enhanced ADS
	  • Reduced latency
	  • Increased update rate

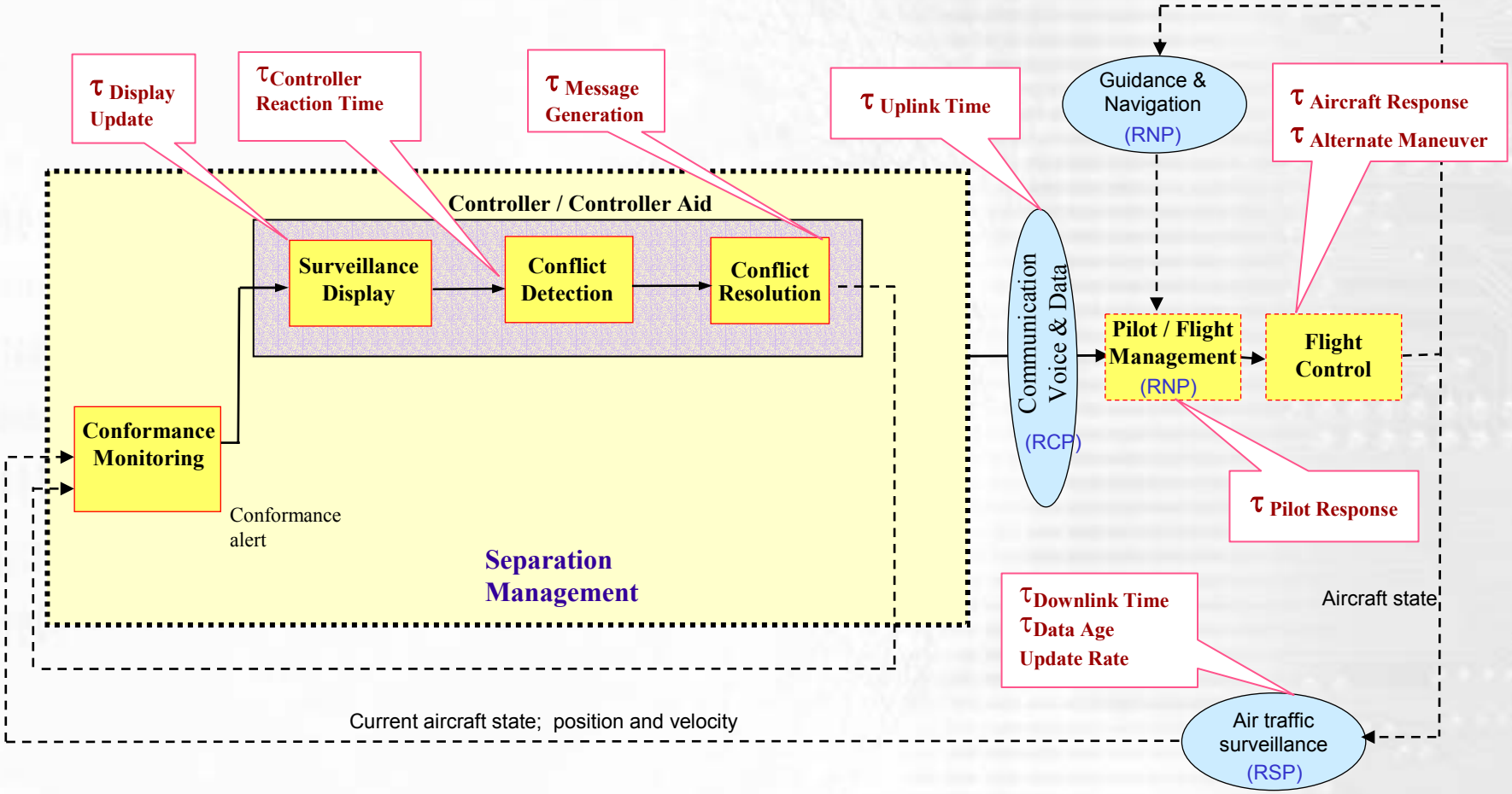
• 4-D trajectory operations	• CPDLC
	  • Reduced latency
	  • Increased throughput

Cost / Benefit Justification • New AOC IP Based Applications	• General IP Connectivity
• Passenger Productivity & Entertainment	• VoIP interface to on-board micro-cell

C, N & S for Reduced Separation

Separation (Lateral/Long.)	Comm. and Controller Intervention	Navigation	Surveillance (Update/latency)
Current Oceanic Performance			
100/10 min* Oceanic * Mach technique	HF voice	RNP-20	40-80 min 5-10 min
NAT 60/10* min	HF voice	RNP-12.6	40-80 min/ 5-10 min
NOPAC/SOPAC 50nm/50nm	ATCDL 7 min (resolution scenario)	RNP-10	30min/1min (ADS)
(Tasman sea) 30nm/30nm	6 min	RNP-4	14 min/1 min (ADS)
Possible Future Oceanic Performance (based upon OP-3 Longitudinal spacing study)			
~20nm/20nm	6 min	RNP-4	1min/15sec (ADS)
~10nm/10nm	3 min Direct voice	RNP-2	15sec/3sec (ADS)
Domestic Performance			
Domestic enroute 5nm/5nm	Direct voice	NA => RNP-1 to 0.5	12sec/3sec (RADAR)
Domestic terminal	Direct voice (1 min Rockman)	NA => RNP-0.3	5sec/2.2sec (RADAR)

Separation Management Control Loop



Communication and Controller Intervention Latency Breakdown – Documented & Proposed Notional

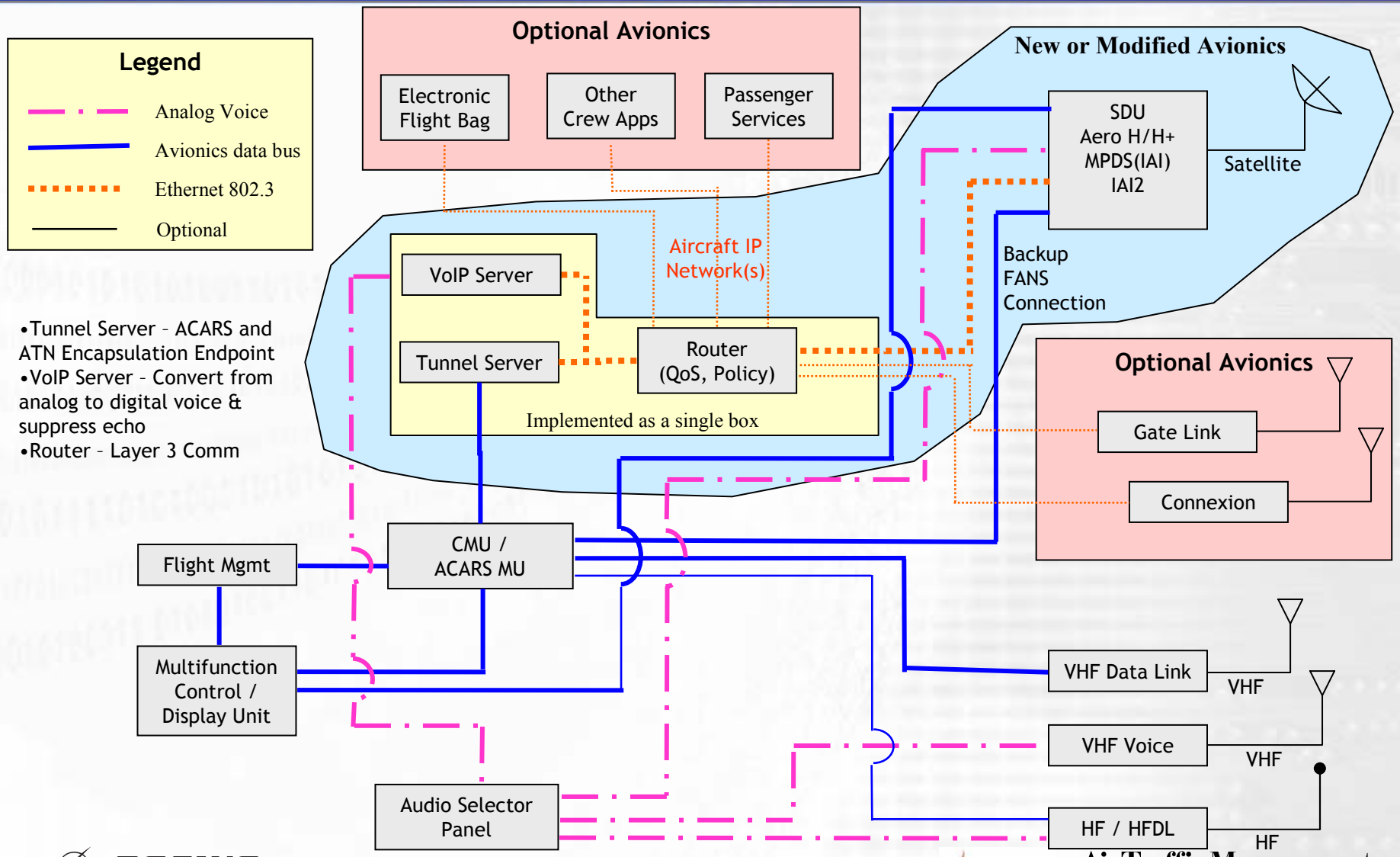
Latency Allocations (sec)	Documented Allocations			Proposed Allocations		
	ICAO 9689 App 5	ICAO 9689 Ammend. 1 App 1 Oceanic (30/30)	Terminal	En-route VHF	Enhanced ADS + Datalink (20/20)	Enhanced ADS + SatCom Voice (10/10)
Data age leaving A/C + Downlink time (max)	61	0	0	0	1	1
Display update interval	60	30	15	36	15	15
Controller reaction time	30	0	18	20	20	20
Message generation time	30	15	0	0	30	0
Uplink time (max)	107	90	4.5	4.5	30	10
Pilot response	45	30	18	20	30	20
Aircraft Response	15		4.5	4.5	4.5	4.5
Alternate maneuver	60	75	15	30	45	45
Total	**408**	**240**	**75**	**115**	**175.5**	**115.5**

- Uplink time is a small fraction of the latency budget
- Voice eliminates message generation time
- Display update time is 3x radar update but can be much less for ADS
- The 10nmi/10nmi separation is roughly equivalent to en-route VHF
- The 2 min. and 3 min. in these latency budgets do not account for the retries that are included in the 3 min. and 6 min. allocations in the last table

Voice and Surveillance Service Concepts

- Enhanced ADS
  - FANS over IP
  - Tunnel FANS ADS messages through an IP tunnel
  - Bypasses ACARS message server to reduce latency
  - Eases transition by limiting avionics changes
  - Packet data SatCom channel maintains reasonable service cost
- Party-line Voice
  - Voice over IP
  - DAMA channel to keep service cost reasonable
  - Reuse SatCom interface into the Audio Control Panel
  - Controller override
  - Multiple options for pilot step-on prevention still requiring evaluation

Avionics Transition Architecture

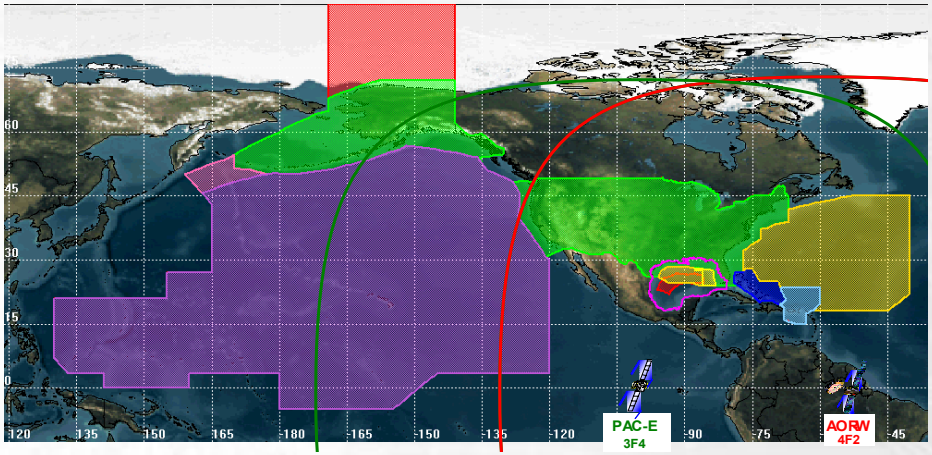


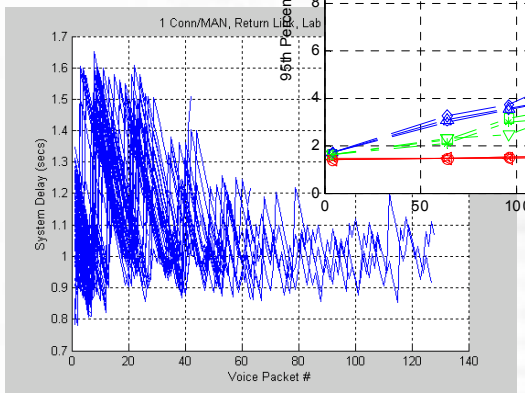
Avionics Considerations

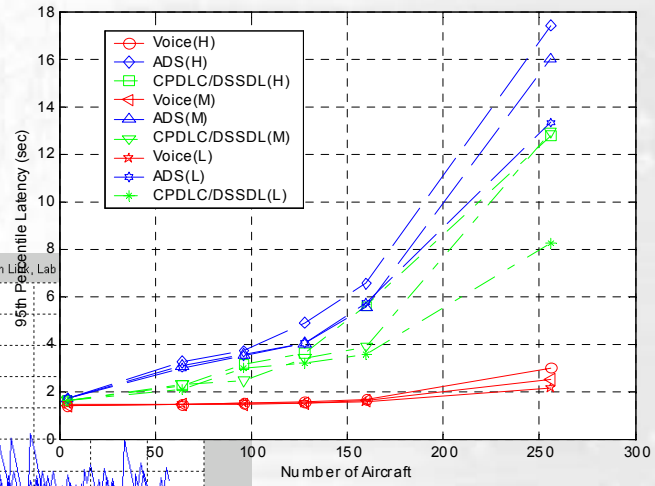
- Cost
  - Key constraint in achieving positive cost/benefits
  - Requires significant cost reduction (2-3 fold)
  - Need to target larger volume price point
- Volume
  - Develop new AEEC specification supporting single box, 6-MCU configuration
- Antenna
  - Latest generation of Aero-H antenna technology extends the market (e.g. to include narrow body jets)
  - Commercial volume/pressure from BGAN may help reduce cost
- Certification [Extended Range Twin Engine Ops (ETOPS) > 180min, Long Range Communication System (LRCS)]
  - Emergency low power mode
  - Passive cooling

Performance Analysis

- Availability
  - Requires BGAN over I-3 spot beams
  - Avionics must also support Aero-H voice and data services in case of failures
- Capacity/Latency
  - Evaluated capacity vs. latency sensitivity
  - Conducted simulations and tests via an MPDS channel
  - 1 Channel handles all of GoM & WATRS
- Party-line voice
  - Subjective testing suggested acceptable performance for oceanic and remote airspace

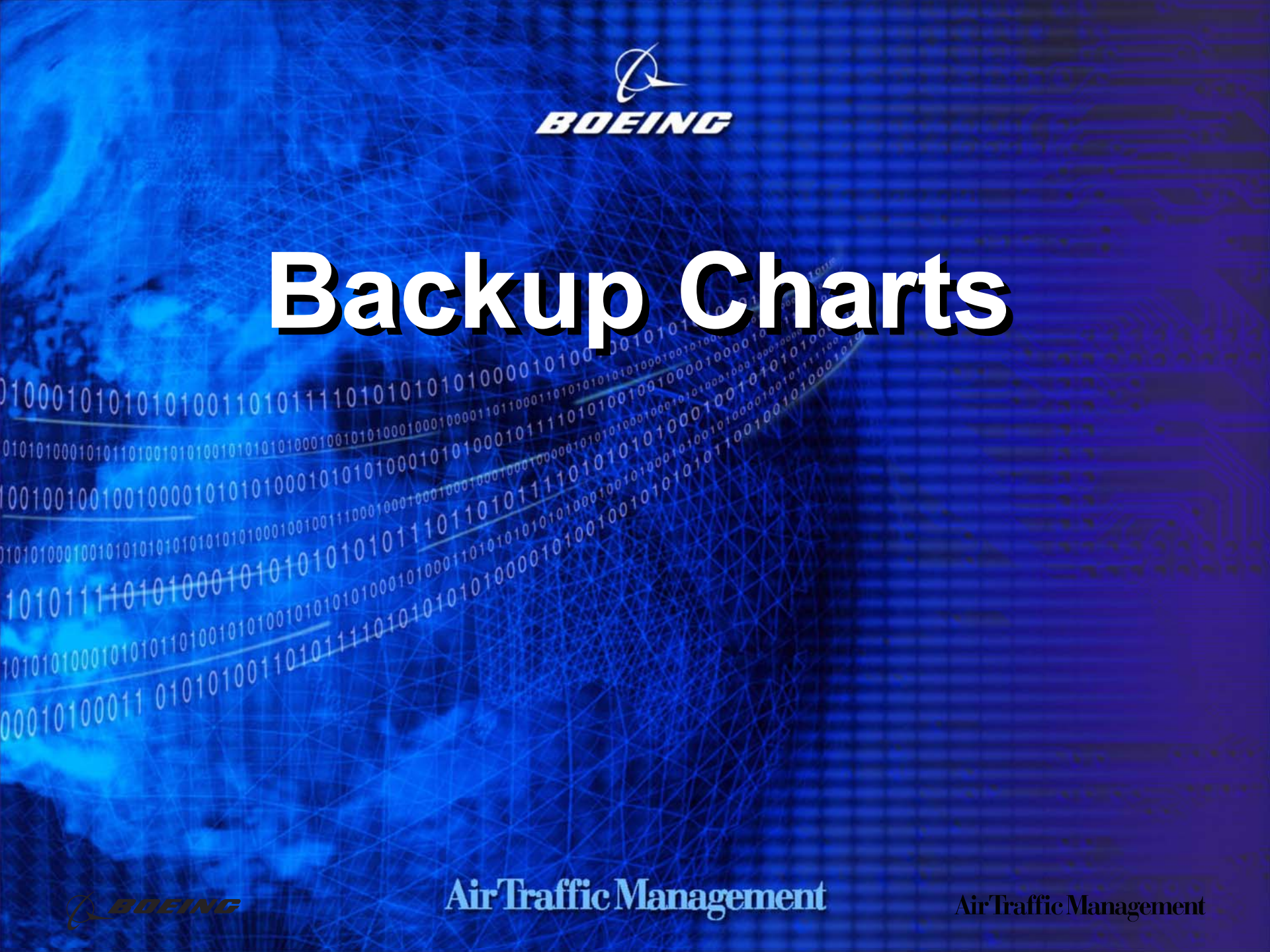






Conclusions

- FANS is the most successful deployed ATC datalink
- BGAN offers the potential to remedy FANS shortcomings, making datalink and SatCom pervasive
- Avionics cost is a key factor that must be addressed early to guarantee success
- Developing a party-line voice service over SatCom that is accepted by pilots and controllers will likely prove the greatest technical/political challenge


BOEING
Backup Charts
Air Traffic Management
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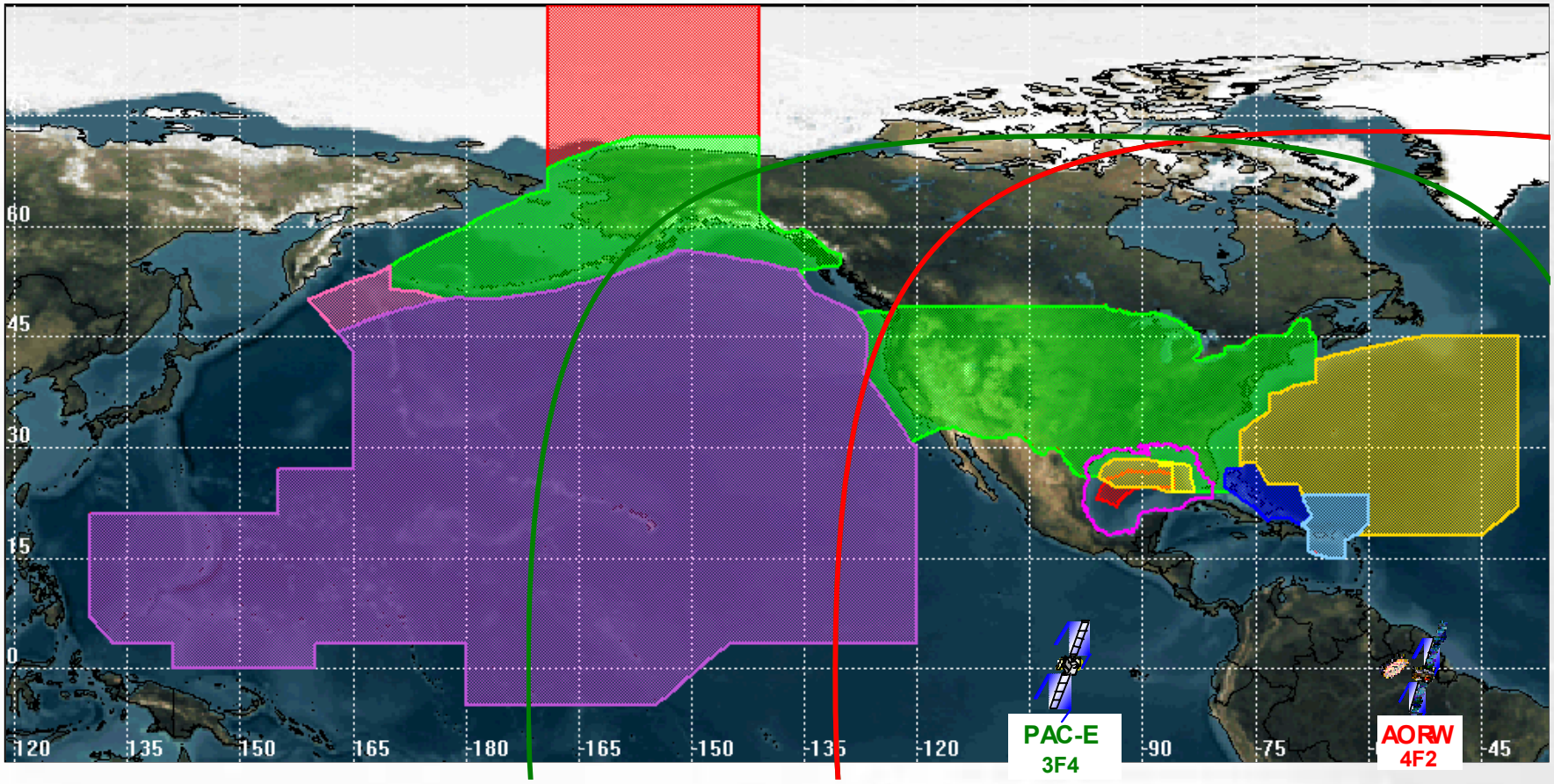
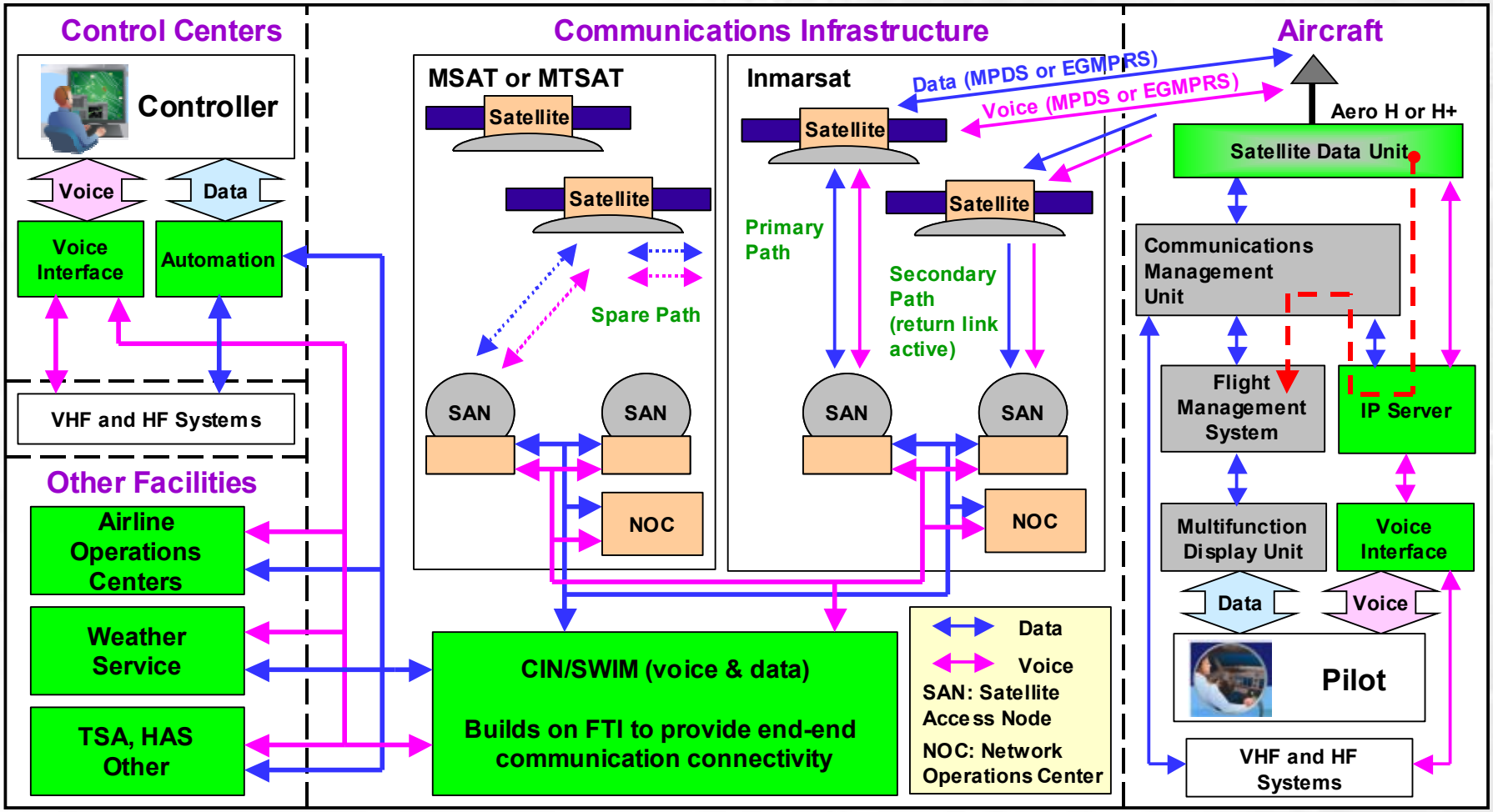
Air Traffic Management

FAA Controlled Airspace and Inmarsat Coverage



End-to-End Transition Architecture



Transition Plan